Presentazione sigla VIRGO

M. Bawaj, Virgo Perugia group

Consiglio di Sezione – 14.07.2022

INFN Istituto Nazionale di Fisica Nucleare

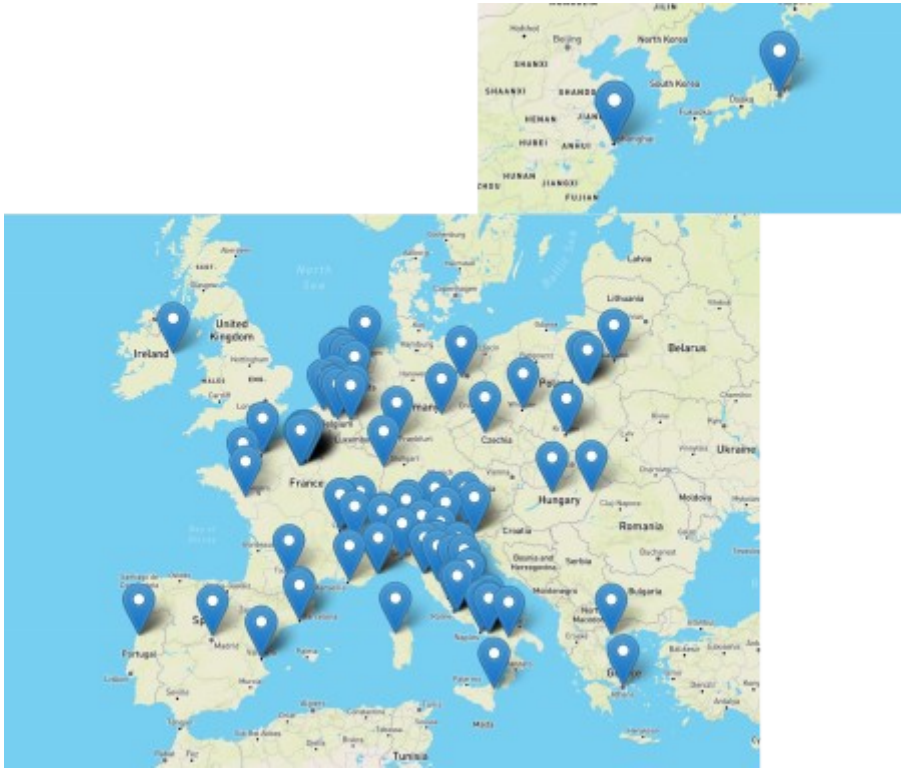
VIRGO

A.D. 1308 unipg UNIVERSITÀ DEGLI STUDI DI PERUGIA

Virgo Collaboration

- ~840 members, ~580 authors, 146 institutions from 16 countries

  +70 members, +130 authors, +15 institutions w.r.t. to last year
- 37 Groups:
- 9 countries represented in the VSC



Organization chart

EGO
Stavros Katsanevas

Project Supervisory Board
Gianluca Gemme

Virgo Steering Committee
G. Losurdo, Spokesperson

Spokesperson
Giovanni Losurdo

Core Program Committee
Francesco Fidecaro & Frédérique Marion

LVK Committees

Advanced Virgo +
Raffaele Flaminio

Technical management
Henrich Heitmann

System engineering
Franco Carbognani

Commissioning
Matteo Tacca

Interferometer ITF
Henrich Heitmann (interim)

Suspension & Mirrors SUM
Helios Vocca

Electronics, Software & Controls ESC
Michal Was

Environment ENV
Roberto Passaquieti

Quantum Noise Reduction QNR
Jean-Pierre Zendri

Detector operations

Run Planning Committee
Alessio Rocchi

Calibration
Loic Rolland

Data analysis
Giancarlo Cella

Burst Group
Florent Robinet

Compact Binary Group
Walter del Pozzo

Continuous Wave Group
Paola Leaci

Stochastic Group
Nick van Remortel

Detector Characterization Group
Nicolas Arnaud

Review Committees
Francesco Pannarale, Archisman Ghosh, Damir Buskulic, Fabio Garufi

Internal Resources

Collaboration Authorship
Stefan Danilishin

Diversity Committee
Tania Regimbau

Early Career Scientists
Miquel Miravet-Tenés & Simone Mastrogiovanni

Ombdusperson
Francesco Fidecaro

Internal and External Communication

Outreach
Livia Conti

Editorial Board VESB
Viviana Fafone & Roberto Passaquieti

Collaboration meetings
Jessica Steinleichner

Computing & Software
Franco Carbognani & Stefano Bagnasco

Connections to LVK bodies

LVK Data Analysis Council
Peter Shawhan, Giancarlo Cella, Hideyuki Tagoshi

... and the various analysis groups

Joint Run Planning Committee
David Shoemaker, Alessio Rocchi, Shinji Myoki

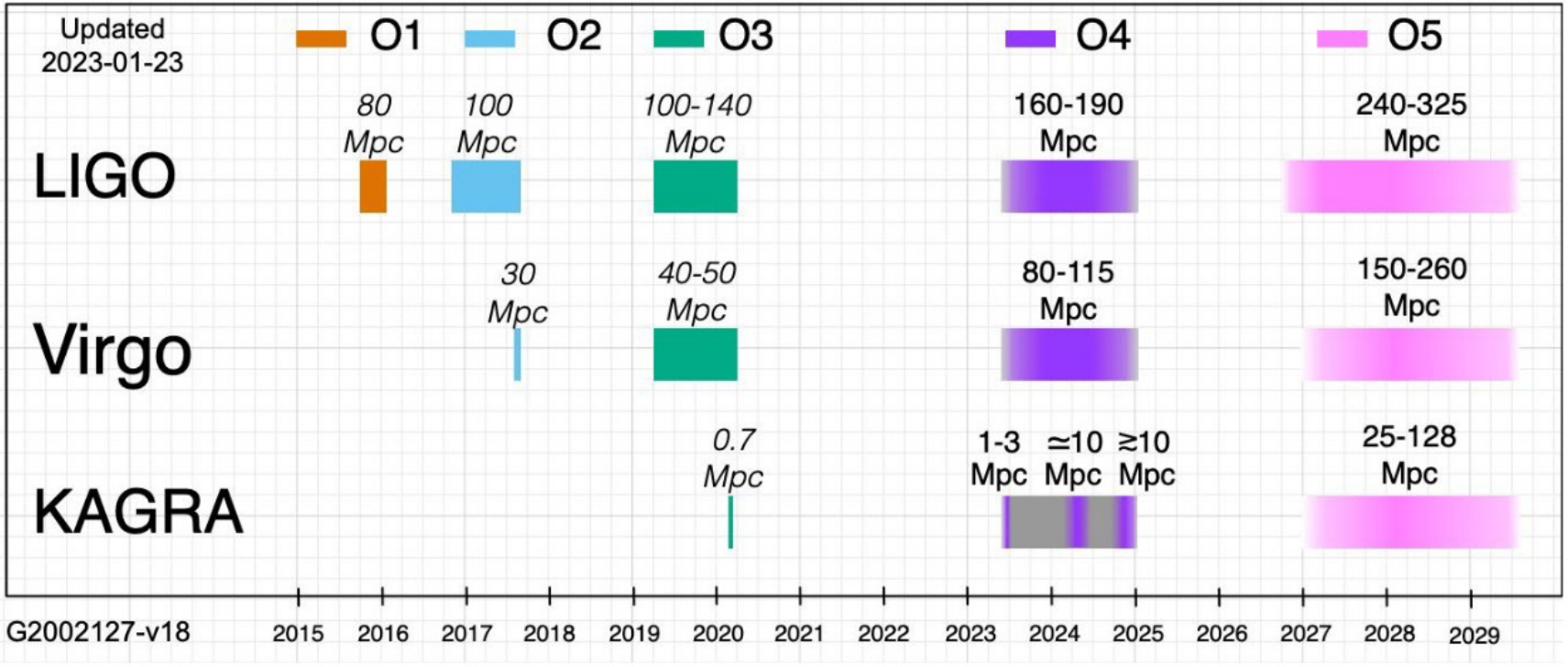
Other LIGO-Virgo-Kagra Committees

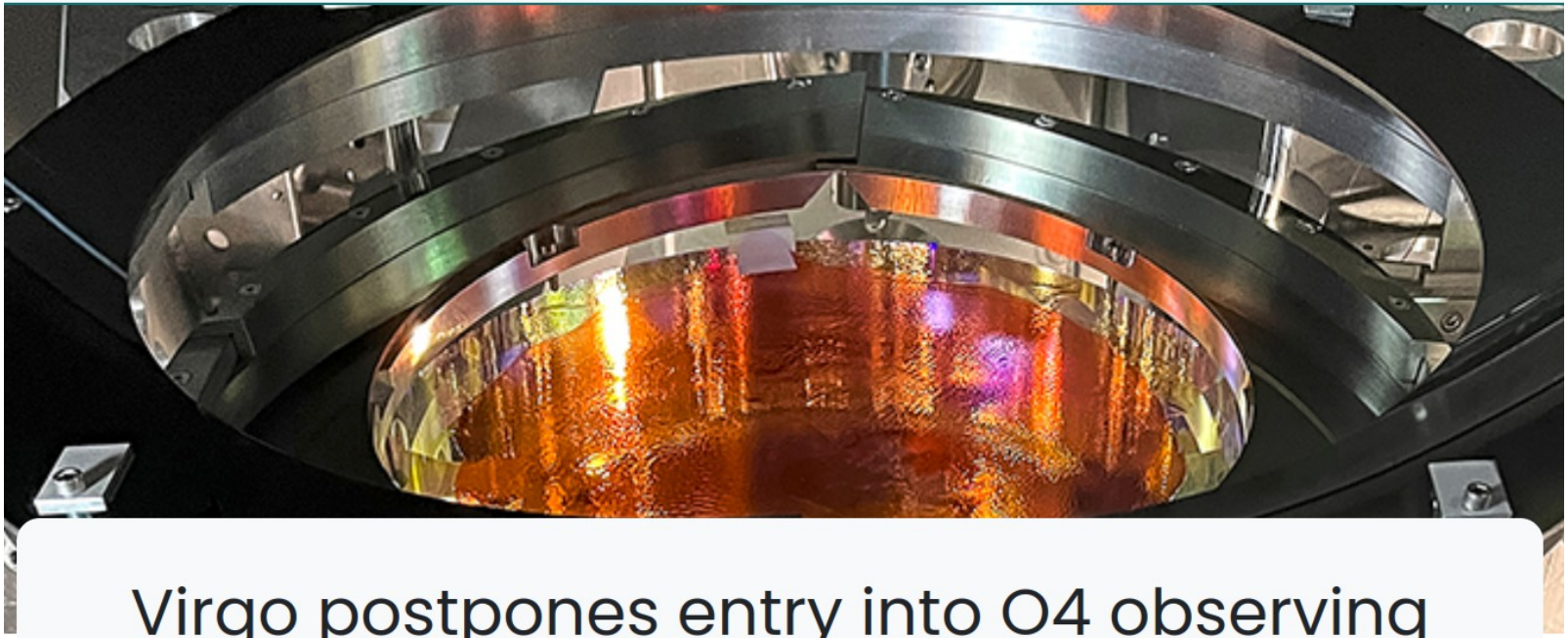
Detection Committee
Frédérique Marion

Climate change Committee

Virgo upgrades and Observing runs

Advanced Virgo configuration(s) → AdV+ Phase I → AdV+ Phase II → Virgo_nEXT concept





Virgo postpones entry into O4 observing run

May 11, 2023

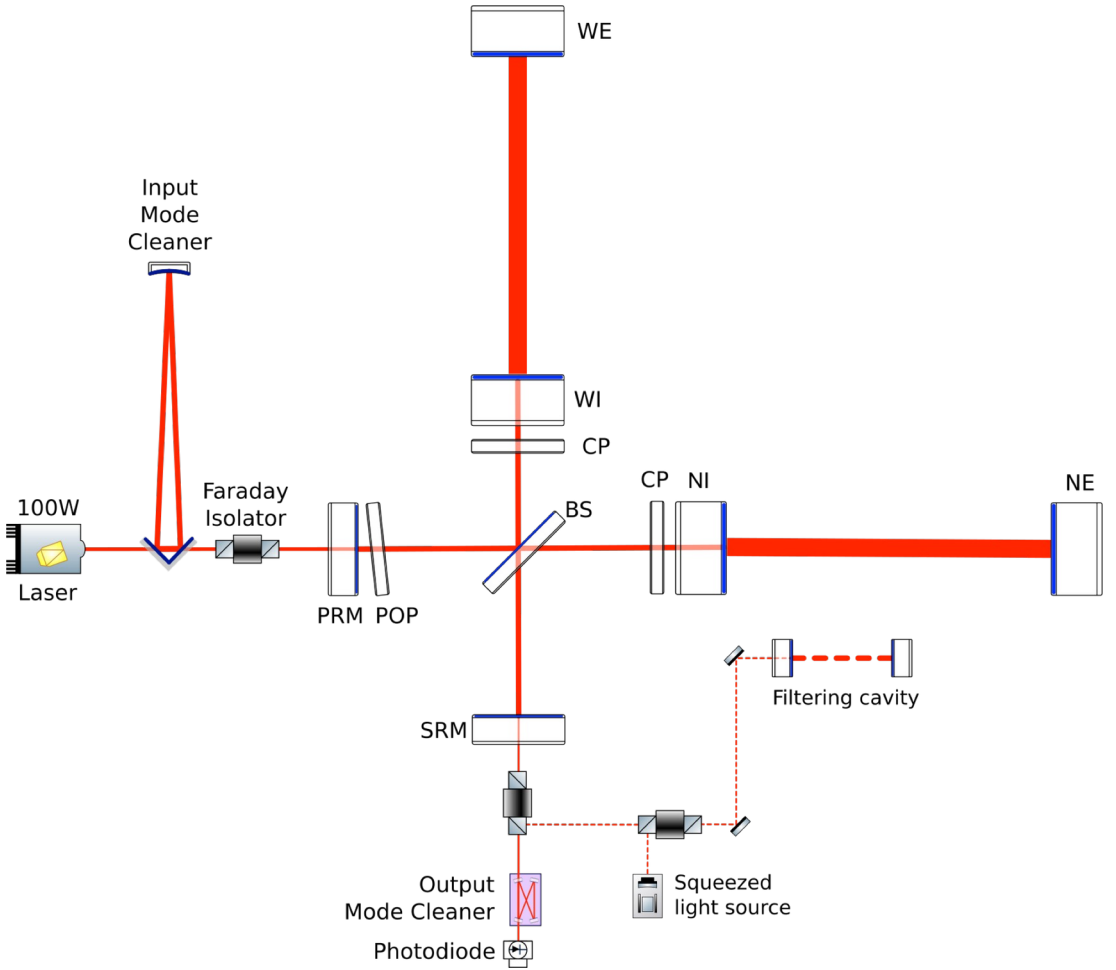
The Virgo Collaboration has decided to postpone the entry of Virgo in the next observing run (O4), scheduled for May 24th, in order to continue the detector commissioning activities and further increase its sensitivity.

Since the end of the O3 observing run in 2020, the Virgo interferometer has undergone a major upgrade to improve its sensitivity for the new joint observing run with the LIGO and KAGRA interferometers. This upgrade has nevertheless required several months for the team to make the detector stable again.
To date Virgo would be able to observe events similar to some already detected in previous observing runs. To go further, a long and intense hunt for the multiple sources of noise that could limit the sensitivity of the interferometer is now necessary. Additionally, subtle technical

Advanced Virgo+ phase I

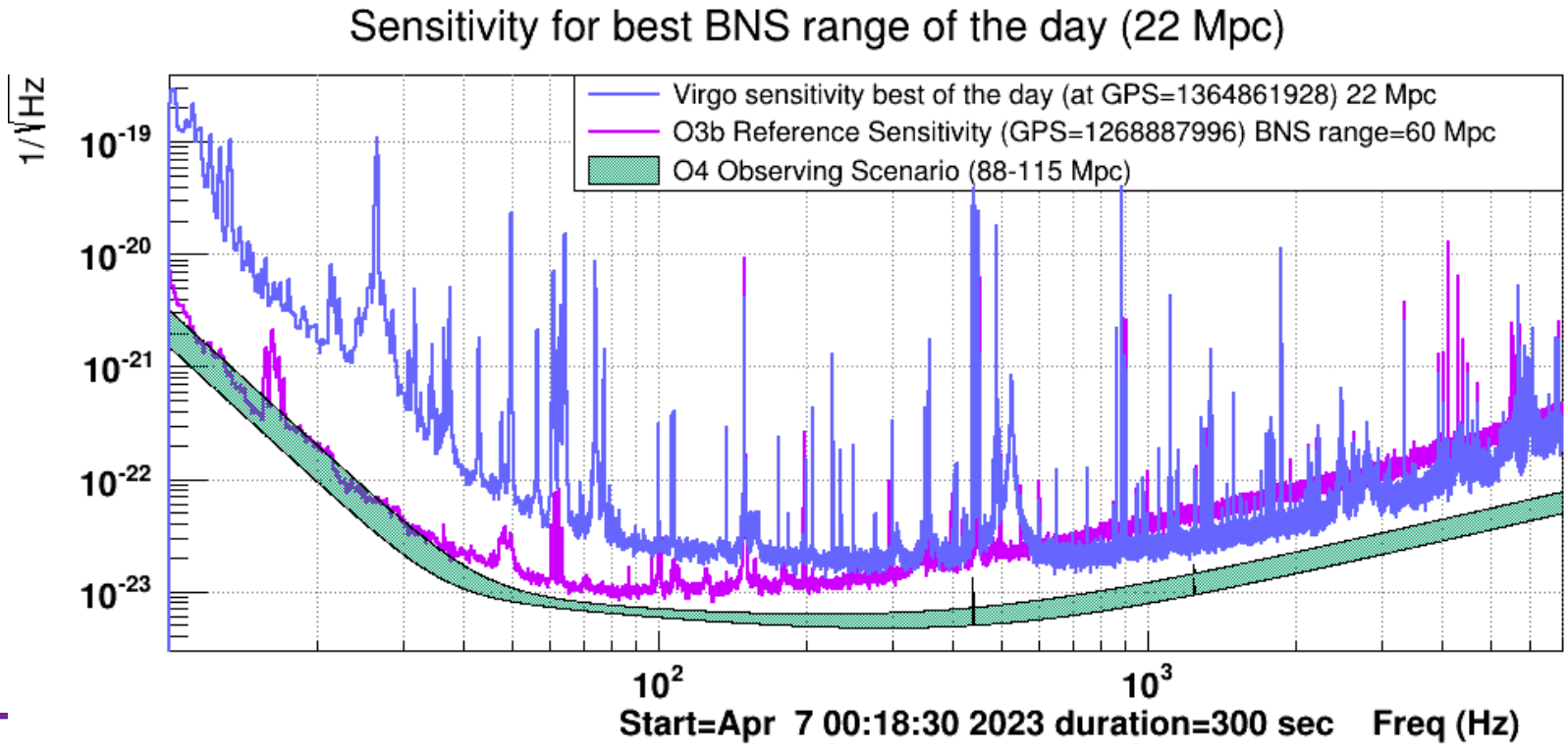
+ Signal Recycling Cavity

+ Frequency Dependent Squeezing



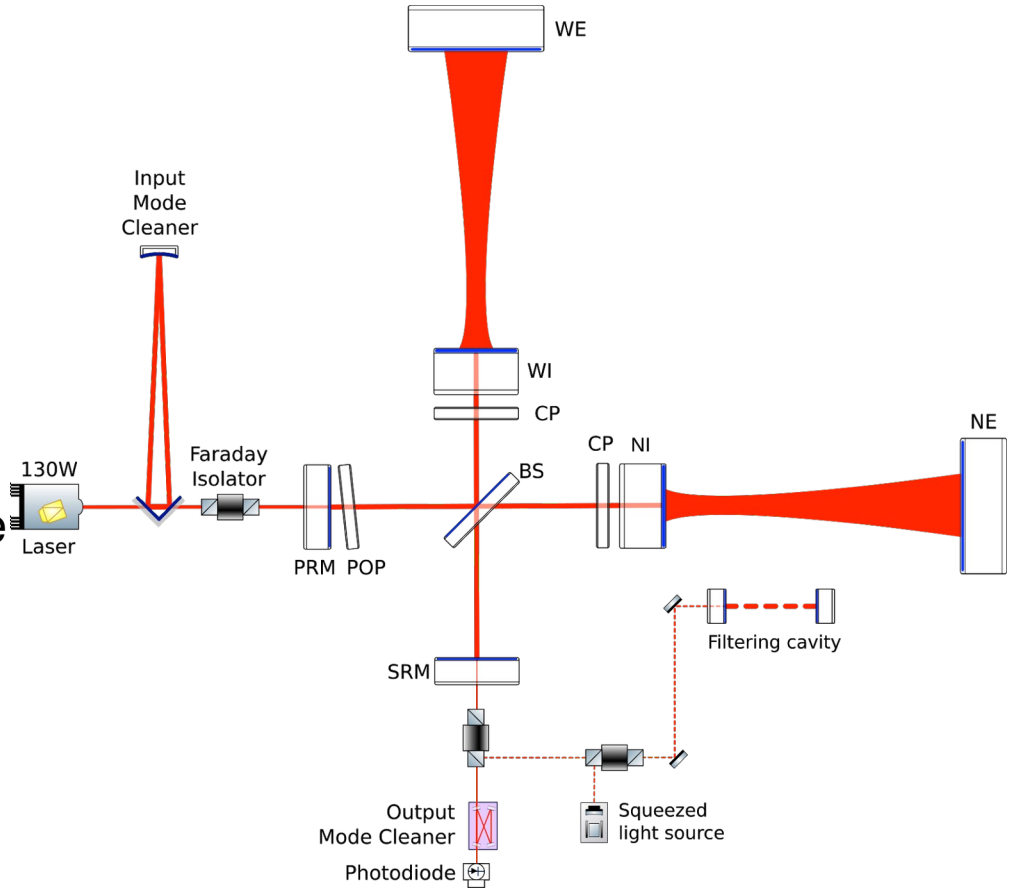
Virgo sensitivity at high frequency

- Sensitivity at high frequency better than in O3
  - The signal recycling cavity does enlarge the detector bandwidth

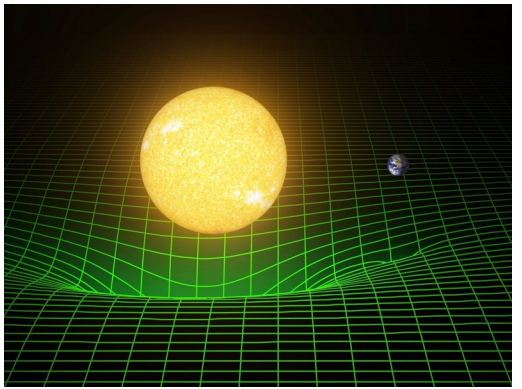


Advanced Virgo+ Phase II

- Main changes
  - Larger beams on end test masses
    - » 6 cm radius → 10 cm radius
  - Larger end mirrors
    - » 35 cm diameter → 55 cm diameter
    - » 40 kg → 100 kg
  - Better mirror coatings
    - » Lower mechanical losses, less point defects, better uniformity
  - New suspensions/seismic isolators for large
  - Further increase of laser power
    - » 40W → 60W → 80 W

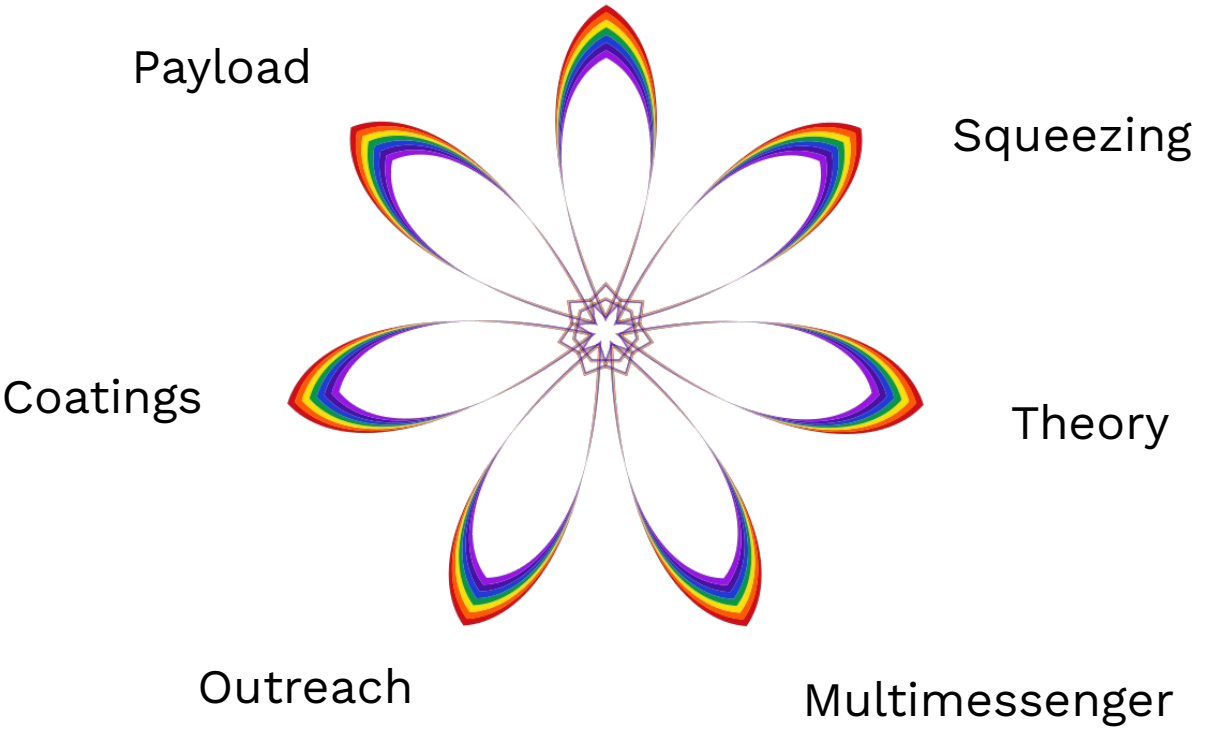


Framework



- ET is the future of the EU GW community
- ET is becoming real
- ET is a great attractor but also a great perturbation
- Virgo community may have an important role in the ET success by contributing to ET
- **We need to balance between the participation in ET and the continuation of the Virgo program**

Research lines



Research on mirror suspensions

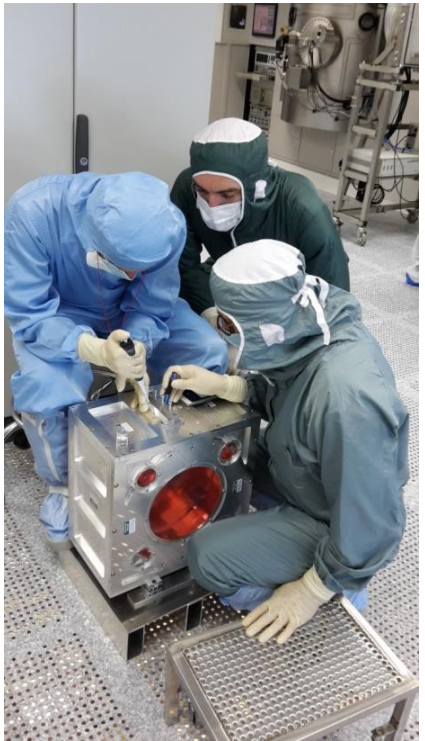
Main research topics: characterization and installation of mirror suspensions

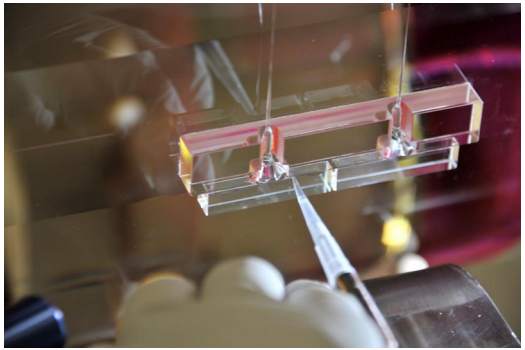
- Mechanical loss measurements and thermal noise modelling
- Optimization and realization of the HCB bonding of all functional parts of the main optics
- Realization of the handling boxes for all the main Virgo optics

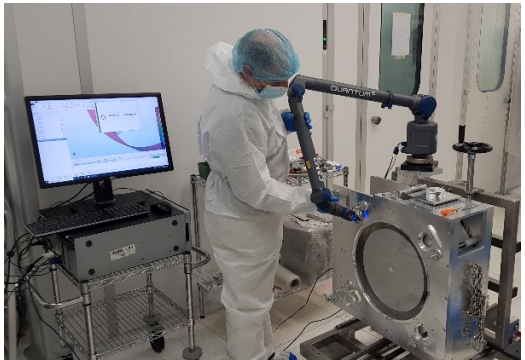
Experimental facilities:

- FARO-CAM2 arm
- Setup for mechanical losses measurement at room and cryogenic temperature
- Materials Testing Machine
- Microscopy (SEM-EDX)
- FTIR spectroscopy
- X-ray diffraction and x-ray fluorescence

HCB procedure at LMA and at positioning test with FARO arm Virgo/EGO site







Research on suspensions

Members:

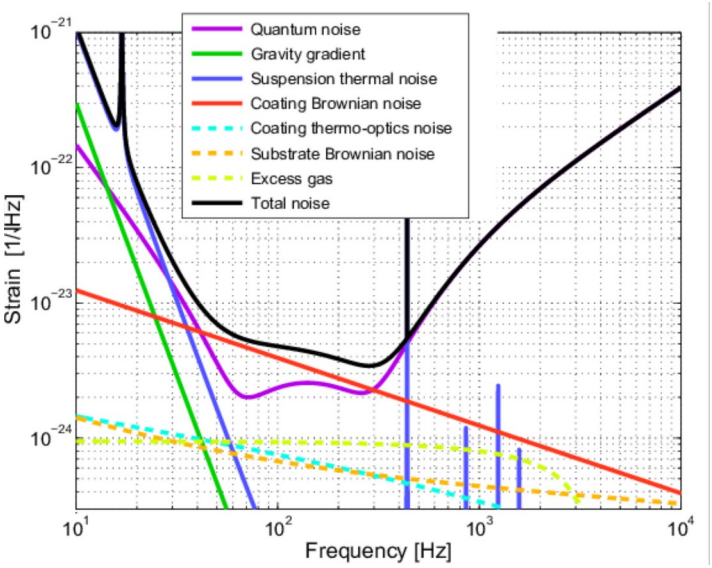
B. Bracco, A. Di Michele, F. Travasso, H. Vocca,

A. Piluso, D. Aisa, S. Aisa

Responsibilities:

- AdV+ SUM (Suspensions&Mirrors) System coordination
- Monolithic suspension assembling coordination

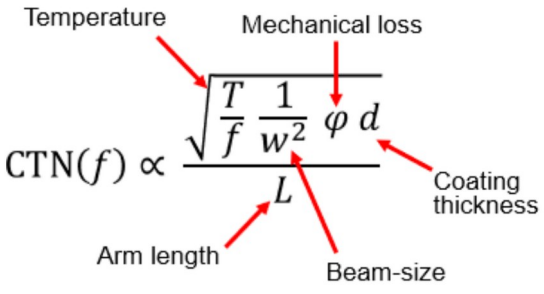
Test Large Mass



Il rumore termico degli specchi è il limite fondamentale alla sensibilità di Virgo nella regione di frequenze 40Hz-300Hz. Per poterlo ridurre vi sono 2 vie:

- Coating con dissipazioni meccaniche più basse
- Specchi più larghi

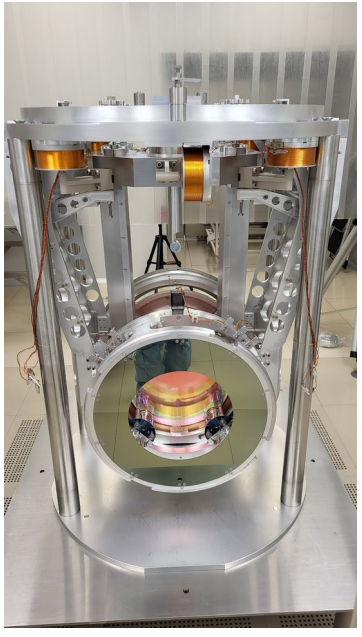
Quest'ultima via prevede l'assemblaggio delle varie parti con una precision intorno ai 10μm, cosa possibile tramite l'uso del braccio FARO

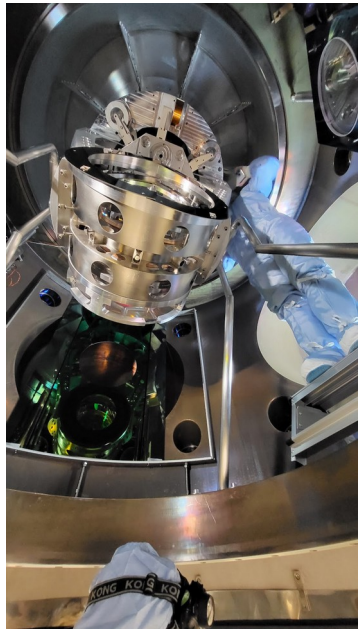


Lavori sulle sospensioni WI e NE

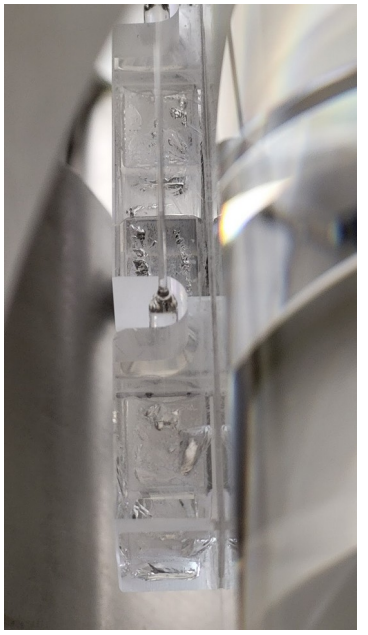
La sospensione della torre WI presentava dei rumori in eccesso dovute ad un magnete rotto che è stato tolto in torre.

La spespensione della torre NE presentava un comportamento anomalo per cui si è deciso di riassemblare tutta la sospensione.



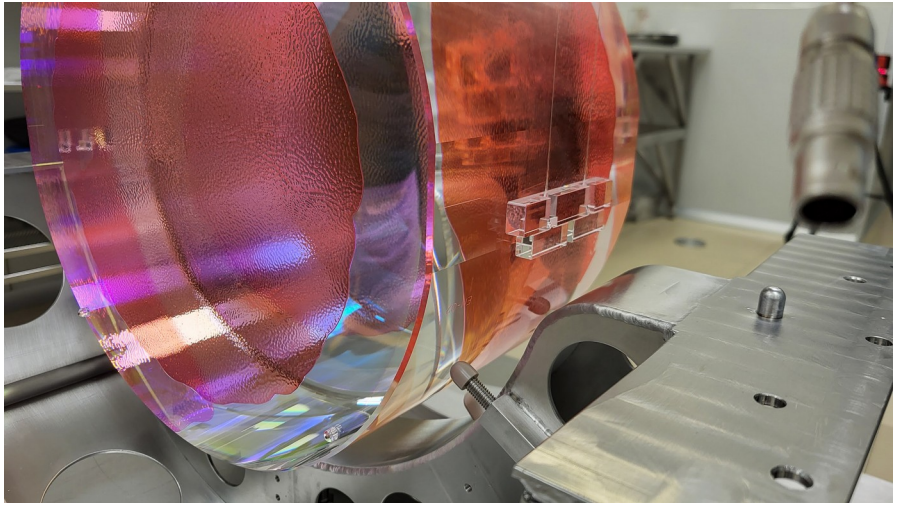


PRIN – Incollaggi rimovibili



Le parti di supporto per la sospensione degli specchi sono costituite da elementi di vetro incollati allo specchio o tra di loro con la tecnica del HCB*. Tale tecnica permette un incollaggio poco dissipativo e molto forte che in caso di rottura delle sospensioni porta al danneggiamento dei vari elementi.

Per questa ragione si sta cercando di sviluppare un incollaggio poco dissipativo ma rimovible senza danneggiare le varie parti



Research on coatings

Main activities: characterization of amorphous oxides and semiconductors coatings

- Mechanical loss measurements (GeNS), thermal noise modelling
- Morphological and compositional characterizations (SEM-EDX)
- Structural characterizations (XRD-XRF, Raman, FTIR and XAS spectroscopy)
- Elastic characterization (Brillouin spectroscopy)

mechanical characterization of optimized silicon substrates

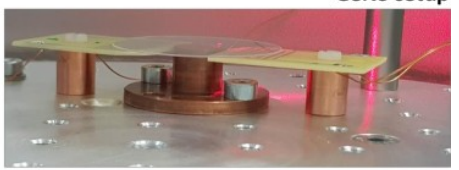
first layers of GaAs deposited (collab. with CNR-IOM), structure & morphology measurements done

Upgrades of experimental facilities:

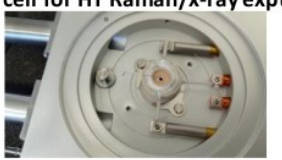
- A new design for a two-chambers GeNS cryogenic has been accepted by the company
- Brillouin setup fully operational for experiments on thin films (upgrade for Q-vector selection and polarization analysis in progress)
- FTIR upgraded with sample holders for grazing incidence measurements
- SEM-EDX: new software for EDX analysis
- High temperature (1500 °C) cell for Raman/x-rays available

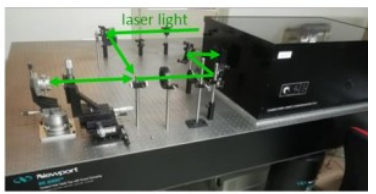
SEM analysis

GeNS setup



cell for HT Raman/x-ray expts





BLS setup

Experiments at external laboratories & synchrotron radiation facilities:

May 2022: @University of Venice: investigation of Argon desorption from silica coatings

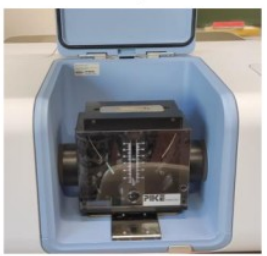
on approved synchrotron radiation peer-reviewed proposals:

Nov 2022: SESAME (Amman, JO) (proposal n. 20190078), *Structure of Ta2O5 and TiO2:Ta2O5 films*

Submitted:

May 2023: FERMI@Elettra (Trieste, IT) (proposal n. 20234083), *Nanoscale study of mechanical properties of amorphous coatings for gravitational wave detectors mirrors*

ATR-FTIR setup



Research on coatings

Members:

B. Bracco,

S. Corezzi,

A. Di Cicco,

A. Di Michele,

P. Sassi,

L. Silenzi,

A. Trapananti,

F. Travasso,

H. Vocca

Presentations at conferences & workshops

- B. Bracco et al., *"Structural characterization of amorphous silica coatings combining specular reflection (SR) and attenuated total reflection (ATR) infrared spectroscopic techniques ", 12th International Conference on Advanced Vibrational Spectroscopy*, August 27 – September 1, 2023, Krakow (PL) - oral
- B. Bracco et al., *"Structural characterization of amorphous silica coatings"*, VISPEC conference, June 14-16, 2023, Perugia - oral
- L. Silenzi et al., *"A structural study of properties of amorphous silica coatings for low internal friction optics"*, Gravitational-Wave Advanced Detector Workshop GWADW, 21-27 May 2023, La Biodola (Isola d'Elba, Italy) – oral
- F. Travasso et al. *"Cryogenic measurements of the loss angle of thin films: a geometric approach"*, XIII ET Symposium, May 8-12, 2023 - oral
- B. Bracco et al., *"A multi-technique approach to the chemical characterization of amorphous coatings"* LVK meeting, March 13, 2023 - poster
- L. Silenzi et al, *"Cryogenic measurements of crystalline substrates"*, Virgo Week, 11 November 2022 - oral
- L. Silenzi et al., *"Effects of thermal treatments on silica substrates"*, LVK meeting, 12 September 2022 - oral
- A. Trapananti et al., *"Short range atomic structure in amorphous oxides for low mechanical loss optical coatings"*, JMC2022, 22-26 August 2022, Lyon (France) - invited oral
- S. Corezzi et al., *"Status of surface Brillouin light spectroscopy of coatings"* Virgo Week, 8 July 2022, Cascina (Pisa), Italy - oral

Thesis/traineeships

- *"Analisi di film sottili mediante riflettività di raggi X",* BSc. (laurea triennale Fisica) – Univ. Di Camerino, E. De Berardinis, supervisor A. Trapananti, October 2022
- ongoing: PhD thesis L. Silenzi (Univ. Camerino)
- *"Caratterizzazione IR di film sottili di SiO2",* BSc. (laurea triennale Chimica) – Univ. di Perugia, F. Tuteri, supervisors P.Sassi & B.Bracco, June 2023

Publications

- L. Silenzi et al, *"Structure and elastic properties of annealed silica coatings for mirrors of gravitational waves detectors"*, in preparation
- L. Silenzi et al, *"Cryogenic measurements of the loss angle of thin films: a geometric approach",* in preparation

Research on the Quantum Noise Reduction

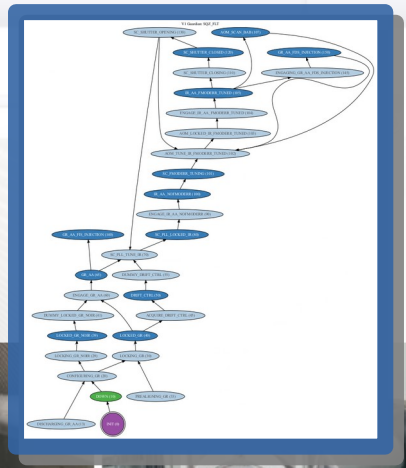
Members: M. Bawaj

Main research topics:

- Commissioning, Automation and Electronics development of the Frequency Dependent Squeezing implementation.
- Software and Electronics development for the EPR squeezing demonstrator.

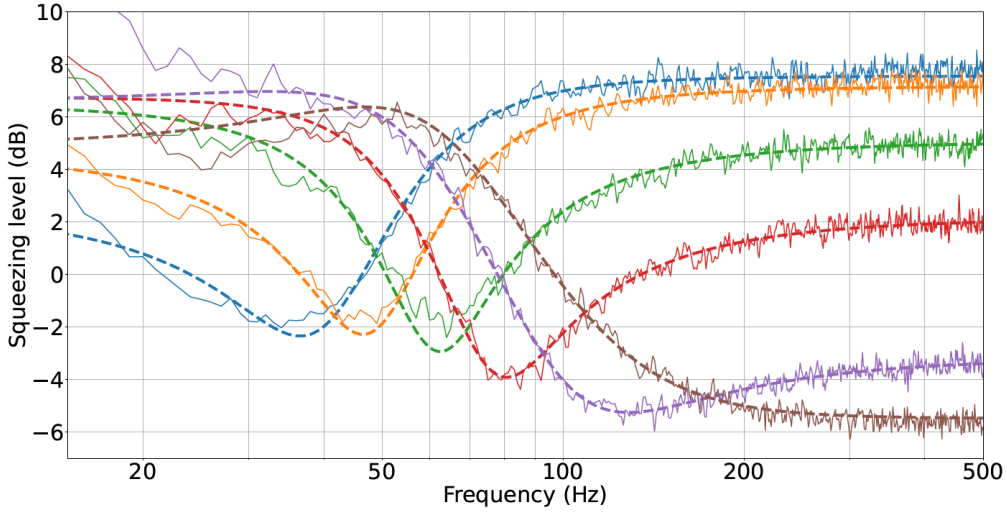
Collaborations:

- with the Kyung Hee University, Korea Astronomy and Space Science Institute and Yonsei University on the construction of the EPR demonstrator.



Commissioning of Frequency Dependent Squeezing

- Frequency dependent squeezing measured down to 25 Hz
- System ready, paper published on PRL



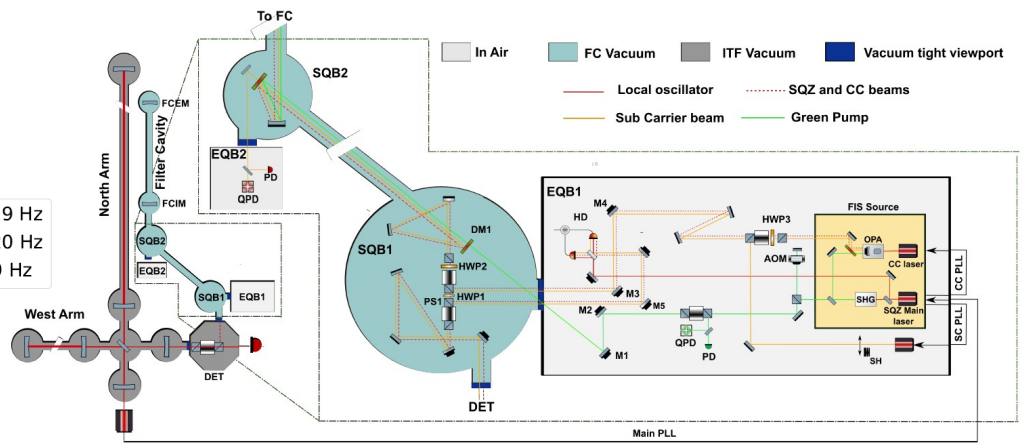
ϕ_{HD} = 87.72+/-0.89 deg, $\Delta\omega_{fc}$ = 43.89+/-0.48 Hz
ϕ_{HD} = 75.51+/-0.39 deg, $\Delta\omega_{fc}$ = 46.82+/-0.26 Hz
ϕ_{HD} = 49.54+/-0.23 deg, $\Delta\omega_{fc}$ = 48.23+/-0.26 Hz
ϕ_{HD} = 31.57+/-0.10 deg, $\Delta\omega_{fc}$ = 50.56+/-0.19 Hz
ϕ_{HD} = 10.95+/-0.09 deg, $\Delta\omega_{fc}$ = 50.19+/-0.20 Hz
ϕ_{HD} = 1.46+/-0.18 deg, $\Delta\omega_{fc}$ = 55.31+/-0.39 Hz

Frequency dependent squeezed vacuum source for the Advanced Virgo gravitational wave detector

F. Acernese *et al.* (the Virgo Collaboration),
H.Vahlbruch, M. Mehmet, H. Lück, and K. Danzmann
Institut für Gravitationsphysik, Leibniz Universität Hannover and Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Callinstr. 38, 30167 Hannover, Germany

(Dated: May 4, 2023)

In this paper we present the design and performance of the frequency dependent squeezed vacuum source that will be used for the broadband quantum noise reduction of the Advanced Virgo Plus gravitational-wave detector in the upcoming observation run. The frequency dependent squeezed field is generated by a phase rotation of a frequency independent squeezed state through a 285 m long, high-finesse, near-detuned optical resonator. With about 8.5 dB of generated squeezing, up to 5.6 dB of quantum noise suppression has been measured at high frequency while close to the filter cavity resonance frequency, the intra-cavity losses limit this value to about 2 dB. Frequency dependent squeezing is produced with a rotation frequency stability of about 6 Hz RMS, which is maintained over the long term. The achieved results fulfill the frequency dependent squeezed source requirements for Advanced Virgo Plus. With the current squeezing source, considering also the estimated squeezing degradation induced by the interferometer, we expect a reduction of the quantum shot noise and radiation pressure noise of up to 4.5 dB and 2 dB, respectively.



Multi-messenger astronomy

Members:

M. Bawaj, M.L. Brozzetti, S. Cutini, G. Greco, T. Matcovich, M. Punturo

Main activities:

- Preparation of tutorials for scientists from the multi-messenger field in the framework of EOSC, IVOA, VO School
- Development of progressive Web Apps for Multi-Messenger Cosmology

  https://virgo.pg.infn.it/maps/

  https://virgo.pg.infn.it/gladenet/catalogs/
- Update to the LIGO-Virgo KAGRA User Guide and lowlatency in O4
- Active Rapid Response Team for immediate GW trigger handling during O4

Related presentations of the group:

- M. Bawaj, “Transient localization web service based on open gravitational-wave data for the multi-messenger community” talk at the GRAvitational - wave Science&technology Symposia (GRASS) in Padova
- M. L. Brozzetti, “GLADEnet: a progressive Web App for Multi-Messenger Cosmology” talk at the LVK collaboration meeting in Chicago
- G. Greco, Invited speaker, “GWapps: to drive multi-messenger researches based on the FAIR approach” at the European Astronomical Society Annual Meeting
- G. Greco, Invited speaker, "ESCAPE to the Future" talk for the Royal Belgium Institute of Natural Sciences
- G. Greco, LOC member & speaker, The IVOA Interoperability Meeting (Northern Spring)

Multi-messenger Virgo group

Members:

M. Bawaj, M.L. Brozzetti, S. Cutini, G. Greco, T. Matcovich, M. Punturo

Related papers of the group:

- M. L. Brozzetti, et al., “GLADEnet: a progressive Web App for Multi-Messenger Cosmology” (preliminary title) paper to be submitted soon.
- Greco, G., et al. “Multi Order Coverage Data Structure to Plan Multi-Messenger Observations.” Astronomy and Computing 39 (April 2022): 100547. https://doi.org/10.1016/j.ascom.2022.100547. + Associated tutorial published in the European Open Science Cloud and promoted by the International Virtual Observatory Alliance
- Greco, G., et al., “Innovative web apps for sky regions in the multi-messenger research” (preliminary title) EAS proceeding to be submitted soon.

Collaborations:

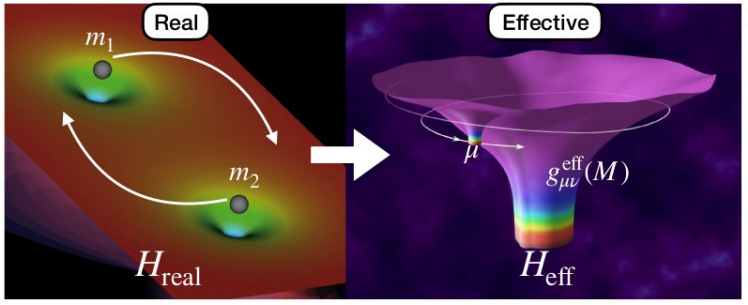
- GECKOrchestrator on the software development at the Seoul National University. Gravitational-wave Follow-up with GECKO and 7-DIMENSIONAL TELESCOPE (paper in the review process)

Research on waveform modelization

Main research topics:

- Effective-one-body approach to gravitational wave models for compact binary systems
- Inclusion of eccentricity effects
- Inclusion of memory effects

EOB approach



[Buonanno-Damour 1999]

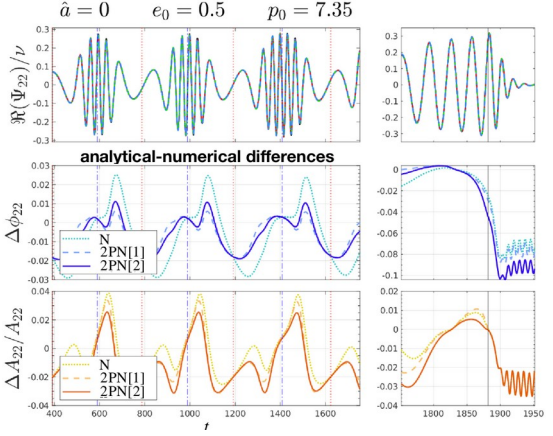
$$H_{\rm real} = Mc^2\sqrt{1+2\nu\left(\frac{H_{\rm eff}}{\mu c^2}-1\right)}$$

Upgrades for the eccentric waveform model TEOBResumS-DALI

$$h_+ - \mathrm{i}h_\times = D_L^{-1}\sum_{\ell=2}^{\ell_{\rm max}}\sum_{m=-\ell}^{\ell} h_{\ell m}\,{}_{-2}Y_{\ell m}$$

$$h_{\ell m} = h^{(N,\epsilon)}_{\ell m}\,\hat{h}^{\rm c}_{\ell m}\,\hat{h}^{\rm nc}_{\ell m}$$

Extra noncircular factors
(inst, tail, memory)



Theory Virgo Group

Members:

G. Grignani, T. Harmark, R. Olivieri, M. Orselli and A. Placidi

Related papers of the group:

- arXiv:2112.05448
- arXiv:2202.10063
- arXiv:2203.16286
- arXiv:2305.14440

Paper on PM EOB Hamiltonian in preparation

Collaborators therein:

- Niels Bohr Institute (Copenhagen) - Troels Harmark
- IHES (Paris) - Alessandro Nagar, Thibault Damour

Outreach

Participants:

M. Bawaj, S. Corezzi, A. Di Michele, G. Greco, F. Travasso

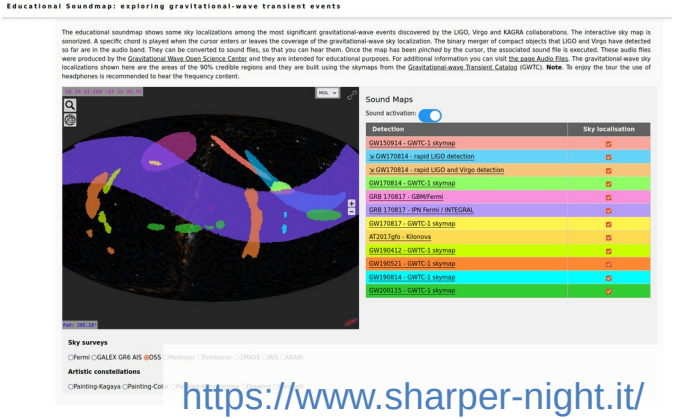
Main group activities:

- publication of the interactive website *Soundmap*

  https://virgo.pg.infn.it/soundmap

- proposal for SHARPER 2023:

  work in progress...



https://www.sharper-night.it/

https://www.festascienzafilosofia.it/

Servizi

Il gruppo continuerà a richiedere il coinvolgimento dei servizi, per lo più meccanici ma anche di calcolo.
Non si prevedono impegni continui per le sospensioni.
È vitale una presenza di circa 2 mesi uomo del servizio meccanico in missione in Giappone (principalmente nei periodi estivi).

Anagrafica

Nel 2023 e 2024 il Gruppo di Perugia mantiene il numero di FTE rispetto all'anno scorso e mantiene anche la divisione di FTE fra gli argomenti di ricerca.

9,4 FTE, distribuiti tra PG: 5,8 e Cam: 3,6

(Lo scorso anno gli FTE erano circa 9)

Richiesta 2024 @ CSN2 ~280k€

Nome	Qualifica	Impegno
E. Z. Appavuravther	PhD	100%
M. Bawaj	RTD-b	80%
M. L. Brozzetti	PhD	50%
S. Corezzi	Prof. Associato	50%
S. Cutini	Ric. INFN	20%
A. Di Cicco	Prof. Ordinario	30%
A. Di Michele	RTD-a	100%
G. Grignani	Prof. Ordinario	20%
F. Marchesoni	Prof. Ordinario	30%
M. Orselli	Prof. Associato	20%
T. Pitik	Borsista	100%
M. Punturo	Dir. di Ric. INFN	40%
P. Sassi	Prof. Associato	40%
L. Silenzi	PhD	100%
A. Trapananti	Prof. Associato	40%
F. Travasso	RTD-b	60%
H. Vocca	Prof. Associato	60%
Tot.		**9,4**